scirrhus cancer, peptic ulcer, foreign body, gumma or extra-esophageal ailment, certainly, esophagoscopy is a justifiable procedure to clear up doubtful points in diagnosis even though it is annoying to the subject. A thoroughly cleansed esophagus, carefully administered intratracheal anesthesia and a good esophagoscope, such as the particularly ingenious Sussmann, greatly facilitate the procedure. When powerful contractures of the cardiac sphincter persistently recur, following most expert divulsive treatment, it would seem necessary always to perform esophagoscopy with the object of searching for and treating locally irritative mucosal lesions.

**Prognosis.** If the affection is properly managed, there is clinical and functional recovery in about 70 per cent. of even well-established instances of cardiospasm. Improvement occurs in 20 per cent. About 10 per cent. of the patients are not permanently benefited by any form of treatment at the most expert hands. The lesion seemingly resists all forms of therapy. In this class are patients extremely emaciated, instances of irritable esophagus where proper treatment cannot be carried out and very likely cases in which there is a congenital defect, or, as Plummer has emphasized, the persistence of a "habit of spasm." For these unfortunates, gastrostomy may be required to save or prolong life. If with cardiospasm there are such associated lesions as gastric ulcer or malignancy, gall-stones, appendix infection or ulceration or inflammation of the cardia or esophagus itself prognosis is seriously limited unless these lesions are amenable to appropriate medical or surgical treatment. Even after the restoration of the cardiac sphincter action, the esophagus may remain much dilated and permit food retention. However, it is surprising how dilatation of the esophagus may persist, and yet such is unaccompanied by troublesome dysphagia, provided the cardiac orifice is patent and the sphincter acts normally.

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# THE SPLEEN AND DIGESTION:

## STUDY I.—THE SPLEEN AND GASTRIC SECRETION.[1]

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The exact rôle of the spleen in digestion is not known. Numerous hypotheses have been advanced and much experimental work has

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been done with contradictory results. Various conclusions arrived at have been:

1. The spleen is an endocrine organ with the function of influencing, in an obscure manner, some portion of the digestive apparatus by way of the blood stream or of activating one or more of the digestive enzymes by an internal secretion.

2. The spleen is a storehouse for the temporary reception of the products of protein digestion, much as the liver is for glycogen.

3. The spleen is merely a diverticulum of the portal system to receive the excess blood rushed to the splanchnic area during the digestive period and to act as an abdominal heart for supplying this blood to the stomach and other abdominal organs as needed.

The idea that the spleen must be of some significance in this regard has been prompted by the gland's intimate anatomic connections with the portal system, marked congestion and swelling observed during the digestive period, proportionately excessive atrophy during starvation and inanition, and by references by many experimental investigators, as well as many clinicians, to a state of hunger and voracious appetite after splenectomy.

The present study approaches the rôle of the spleen in digestion from the viewpoint of its relationship to the stomach, especially the effect of splenectomy on gastric secretion. All previous work on this aspect of the problem is foreign, and most of it given in publications not readily accessible; for this reason I am reviewing the literature in some detail.

## REVIEW OF THE LITERATURE.

The spleen and stomach from the earliest times have been supposed to possess some close interrelationship. Stukeley in his most excellent dissertation on the spleen, published in 1723, definitely assigned to this organ as its second major function the duty of being an adjunct to gastric digestion, and admirably reviewed the tenets of previous authors. He approached the subject thus:

"But let us proceed to what I imagine one of Nature's primary purposes in the formation of this curious organ (spleen): That is, for an assistant of the great business of digestion or concoction of the aliment in the stomach; the first and highest importance of all others, for preservation and support of the individuum, the mainspring of the wonderful machine, rightly by Plato from Hippocrates called the primum mobile, alluding to the imagined first agent of the rotation of the huge celestial orbs. This is no new opinion but rather an old one, well started by the Ancients, but neglected by their successors, especially the Moderns. The divine Hippocrates, to whom scarce any truth was unknown, thought the office of the spleen was to help concoction, by drawing off the superfluous humidity from the stomach, whom Aristotle copies after. Others supposed this assistance was performed by furnishing the stomach with its acid ferment, whence it excited hunger, stirring up the vis appetitrix. Aristotle made it, being a sanguineous organ, the concocter of the crudities that otherwise would offend the stomach. Some have thought the spleen's fancied melancholy useful to the stomach, by its acid, austere, styptic and astringent quality which contracted and strengthened the fibers thereof and enabled it the better to concoct and retain the aliment whilst digested and expel it afterward, as Galen says in the lion, leopard, bear, wolf, pard, etc.; and the Arabians fell pretty much into this notion, for they always thought it strengthened the stomach."

Stukeley was of the opinion that any common observer in anatomy naturally would be tempted to conclude that the spleen has some relation to the stomach when he found the one placed directly under the other, and with the intimate intercommunications by means of their common veins, arteries, nerves and connections that exist invariably in all creatures.

He was led to answer the questions why the principal bloodvessels of the stomach arise from the splenic artery in its direct route to the spleen and why vessels go immediately from the spleen to the stomach, as ordinarily do the vasa brevia, by formulating the theory that the spleen acts as a "heart to the stomach," that it is a magazine, diverticulum or necessary receptacle of the blood for the use of the stomach, ready, as occasions and emergencies require, to send plentifully of its supply into the gastric vessels, later when the blood is not needed there to receive it back again. This is of great service in a part that must so suddenly alter its dimensions, extend its bulk and contract itself in its great business of digestion as does the stomach.

However, this was not the only office wherein the spleen was subservient to the stomach, for (in common with Aristotle, Anonymous Graecus and Galen, who affirmed that the spleen assists in warming the stomach, and with the great Vesalius, who said *Lienem suo calore innato ac frequentibus quae illum intertexunt arteriis ventriculi concoctionem favere*) he advanced the opinion that the spleen by its proximity, great vascularity and timely congestion furnishes heat to the stomach. He asked "— does not nature proclaim its (spleen's) great eminence by its situation, being placed on the left side of the stomach where digestion is chiefly performed, and closing it up, as it were, like the door of a furnace, that it may have an equable warmth quite around so that the spleen alone in this single requisite of heat is apposed to all the rest of the bowels put together that encompass the stomach." He further adduced as proof of this assumption the "notorious" and "terrible" effects produced by eating ice and snow liquors in hot countries! Is this not in accord with the fancy entertained by the ancients "that creatures which drink much have larger spleens, whose business it is to warm the stomach against such a quantity of cold fluid"?

Stukeley's position can then be summarized happily in his conclusion "that if the stomach in the opinion of Q. Serenus deserves to be called *Rex totius corporis,* the spleen deserves to be called its viceroy."

The "immortal" Haller in reviewing hypotheses concerning a *secretio lienalis* mentioned the idea that had been advanced that the spleen elaborated an acid juice which, sent to the stomach through the vasa brevia, aided in digestion. He himself denied such a function. (*Lien non est acidus. Vasa brevia nihil a liene in ventriculum sani hominis vehere; et lange minus aliquid in arteriam remittunt.*)

Oken maintained that the gastric juice and chyme undergo a process of oxidation, and that the spleen in this respect holds a somewhat similar relation to the stomach to that which exists between the air and the lungs or the placenta and the fetus.

Finally, Burdach denied any relationship between the two organs because *aucune des hypothèses dans lesquelles on fait concourer ce viscere a la digestion, ne repose sur la moindre preuve.*

However, Baccelli has been credited generally with being father to the hypothesis of a distinct functional relationship between the spleen and the stomach, for he was the first scientifically to base his deductions on original clinical observations and anatomic studies. In 1868, at Rome, he gave his theory to the world in a discussion on malaria. In his extensive experience he had noted that during the prodromal and defervescent periods of paludism the patient frequently showed a voracious appetite; conversely, during a period of malarial cachexia a special dyspepsia intervened, resistant to all therapy. In the first instance only a soft evanescent splenic tumor was present, in the latter a lasting hyperplasia of more or less of the organ modified only by the amount of hyperemia. This dyspepsia was most marked toward albuminoid food material, and he found in the vomitus of the patients unchanged meat fibers, even after two or three days, indicative of impaired peptic activity.

Baccelli then carried on anatomic studies in which he demonstrated a definite gastrosplenic circulation. He found that the veins of the vasa brevia form five or six rectilinear canals, with intercommunicating smaller vessels, from the spleen to the cul-de-sac of the stomach, which are devoid of valves, so that the blood can pass in either direction; it may go at one moment to the stomach, at another to the spleen or remain in the interposed vascular system. These vascular connections he designated as *una piccola circolazione addominale.* The largest number of gastric glands are situated in the cul-de-sac at the area supplied or drained by these veins. The manner in which the blood streams of the vena coronaria sinistra and vena splenica are confluent he summed up as follows: *Difatti, dalla milza a capillari dello stomaco pe'vasi brevi- da'capillari dello stomaco alla vena coronaria sinistra- dallo stomaco pe'vasi brevi alla* *milza- dai capillari della milza alla vena splenica- dalla vena splenica e dalla coronaria sinistra al confluente.* On the basis of this anatomic relationship Baccelli formulated the following hypothesis: Considering the large amount of carbon entering into the molecular composition of pepsin it seems likely that the spleen is deputized to furnish this material, in the form of carbonic acid, to the peptic glands for their proper function. The stomach dilated by the blood given it compresses the splenic vein against the vertebral column, obstructing thus the venous splenic outflow and causing still greater splenic engorgement, with the forcing of blood through the veins of the vasa brevia to the cul-de-sac of the stomach. Thus the *ragione d'essere* of the little venous abdominal circulation was explained, in which the carbonic acid was used in perfect antagonism to its rôle in the little thoracic circulation where it is eliminated.

Baccelli's anatomic research was repeated by Roseo in 1870 and confirmed in all particulars. Nothing further was done on the subject until 1901. In this year Tarulli and Pascucci, working in Luciani's laboratory, carried out a set of experiments on dogs in which they determined the digestive activity of the gastric juice before and after splenectomy. Gastric fistulas were made according to Claude Bernard's method. A preparatory meal, consisting of 500 gm. each of cooked meat and broth and 200 gm. of bread, was fed with the idea of exhausting the pepsin accumulated in the gastric glands. Sixteen hours later the mucous membrane of the stomach was washed out with isotonic salt solution and a secretory meal consisting of 100 gm. of cartilage and tendons given. The resulting secretion of gastric juice was collected and tested for peptic activity by placing 1 gm. cubes of coagulated egg white in 10 c.c. samples of pure juice for twenty-four hours at 39° C., the amount of digestion being determined by the loss in weight of the cubes after this period. The results obtained led Tarulli and Pascucci to the conclusion that the digestive power of the gastric juice is constantly decreased to a greater or less extent after splenectomy. Furthermore, they found that by feeding an infusion of congested spleen, that is, spleen excised five or six hours after a meal, the digestive power was increased again for from one to three days. From these results they assumed that during gastric digestion the spleen elaborates a pepsinogenic substance which is carried to the gastric glands through the blood stream and induces an increased amount of pepsin secretion.

Gallenga, in 1902, performed some digestive experiments on a patient splenectomized for a large blood cyst of the spleen. The spleen was large and hard and showed hyperplasia of the connective trabeculæ, with reduction of the tissue propria. The patient recovered from the operation, maintained a good appetite and had no subjective digestive disturbance. A month later Gallenga started his experiments with three test-meals: the Ewald (vegetable), Leube (vegetable and meat) and Ferrannini (meat). No determinations were made preceding splenectomy. His results he summed up as follows:

1. Insufficient and delayed digestion of albuminoids *in vitro* by the filtrate of the gastric contents.
2. Protracted and augmented chloride secretion, especially of combined hydrochloric acid.
3. Abnormal amount of fermentation.
4. Retarded motility of the stomach.
5. Increase in activity of the pepsin of the gastric filtrate in artificial digestion by the addition of an extract of lamb's spleen.
6. Subjective phenomena on the part of the individual showing a certain gastric hyperexcitability with the paste of Ferrannini and a discrete diminution in the body weight.

From these data Gallenga concluded that:

1. The spleen most probably has an active part in the gastric digestion of albuminoids, as is proved to occur in pancreatic digestion.
2. This action of the spleen must depend on an internal secretion, pepsinogenic, which exerts an influence on the quantity of the juice poured out and the activity of the pepsin.
3. In persons splenectomized the peptonization of albuminoids in the stomach and *in vitro* with extracted gastric juice is markedly delayed and diminished, although in a certain degree compensated for by an augmented chloride secretion.

In 1903 Silvestri performed some animal experiments which led him to the conclusion that the digestive power and the quantity of the gastric juice are constantly augmented after splenectomy. He found that in the dog and cat immediately after removal of the spleen gastro-intestinal phenomena intervene, and that though appetite is conserved, weight is lost. When the animals were sacrificed after four days an enormous dilatation of the stomach was observed which Silvestri thought could not be blamed to operative trauma. To three dogs before and after splenectomy he administered a secretory meal of soup and meal and injected apomorphin after four, six and eight hours respectively in order to secure vomiting. He observed that the material vomited was in less quantity and in a more advanced state of digestion in the splenectomized dog. Later he fed animals a mixture of bread with 200 gm. of meat divided into small cubes, and after five hours opened the stomachs; they contained brownish liquid with pieces of meat more abundant and larger in the control animals than in the splenectomized animals. In artificial digestion with the non-filtrated gastric contents he found less peptic activity in splenectomized dogs, but on the contrary more activity after filtration of their chyme. This, he considered, proved that digestion was more advanced in those splenectomized. Again, using *in vitro* experiments with filtrated gastric contents, he found a hyperpepsia following removal of the spleen. Splenectomized dogs had the capacity of transforming enormous quantities of albuminoids in their stomachs.

In a later communication he stated that:

1. An internal secretion of the spleen with trypsinogenic or pepsinogenic function cannot be demonstrated.
2. The spleen plays a mechanical part in digestion and can be considered as a regulator of the circulation of the abdominal digestive organs.
3. The infusions of spleen in the height of digestion most probably exert influence on pancreatic extracts and the gastric mucosa by virtue of their leukocyte content, since these cells, as has been shown by other workers, contain a ferment, kinase, with digestive powers.

Silvestri reported the case of a woman of thirty with syphilis who had a large spleen and was splenectomized. Four months later she aborted a two months' fetus, after which Silvestri took up the study of the patient's gastric motility and chemistry. He found the gastric motility intact while the digestive power was superior to normal.

Likewise Tini, in 1909, found an augmentation in the gastric secretion and peptic activity, concluding that there is an antagonism between the pancreas and the stomach in the mode of action exercised on them by the spleen, splenectomy decreasing the trypsin function of the pancreas and augmenting the pepsin activity of the stomach.

Betti, in 1909, reported observations on a dog with a gastric fistula. He used Mett's method of determining peptic activity and also introduced 10 gm. meat cubes into the stomach. These cubes lost from 2.8 gm. to 3 gm. in weight before splenectomy and only 0.6 gm. to 0.4 gm. after splenectomy. The dog became markedly voracious. The author explained the objection that splenectomized animals live and digest well by citing the fact that animals can also live without a stomach. His deductions were therefore (1) in splenectomized animals the digestive power is notably diminished and (2) the spleen intervenes in gastric digestion by sending a substance that can be considered, as much from its genesis as its action, analogous to the enterokinase of Pawlow, and with all probability it serves to activate the zymogen into active ferment. This would easily explain the observations of Baccelli that the spleen in malaria, sclerotic and inelastic from the process of chronic splenitis, receives much less blood than a spleen normal and elastic; as a result there is a notable diminution in kinase.

Gross, in 1910, reported the case of a young man who was splenectomized ten hours after rupture of the spleen due to a hoof-kick in the abdomen. After recovery he attended a reception at which he overate and was seized with abdominal cramps. This suggested to Gross the advisability of investigating the patient's digestive juices. The amount of trypsin in the duodenal contents and stools was normal. The peptic activity of the gastric juice was determined after an Ewald meal by the method of pepsin determination introduced by Gross and now known by his name (precipitation of faintly alkaline solutions of casein by means of acetic acid; no precipitation on complete digestion). He found, four weeks after splenectomy, a marked decrease in the pepsin strength, which gradually rose almost to normal within three months and was completely normal at the end of seven months. At the same time he carried on studies of the blood and noted a relative lymphocytosis which disappeared gradually in ratio as the strength of the pepsin rose. From this he suggested an interrelation between the lymphocytosis and the decrease of peptic activity.

Trampedach, in 1911, carried on a careful and exhaustive series of researches:

In the first investigation he sought to simulate the method of Gross as nearly as possible; a dog was given a test breakfast, which was removed by the stomach-tube. Chyme was obtained which was not acid, a finding which the experimenters, in view of the newer observations on the distribution of the acidity of the stomach in layers, did not consider wonderful. Later a Pawlow cannula was inserted into the dog, the chyme obtained after a test breakfast and an analysis for its pepsin content made. The determinations were carried out with Mett's tubes filled with wether serum instead of egg albumen.

In the second investigation Trampedach attempted to avoid the incomplete emptying of the stomach, which might have happened in the first investigation. To this end a special cannula, 2 cm. in diameter, was inserted into the duodenum. By the introduction of rubber balloons, barriers were put up and removed at will in order to have all the experiments exactly alike. As test-meals, 100 gm. portions of sterilized flesh and 25 gm. portions of dried ground white bread were used. The chyme obtained was tested (1) for its content of dissolved nitrogen in the filtrate, and by this means the degree of digestion in the stomach determined; (2) it was put with equal parts of tenth normal hydrochloric acid and let stand to digest for twenty-four hours, the amount of peptic activity then being ascertained by the determination of the dissolved nitrogen in the filtrate; and (3) it was investigated for proteolytic power by means of Mett's tubes.

In the third investigation pieces of mucous membrane were cut from different places of a dog's stomach and the spleen extirpated at the same time. The infusions from the pieces of mucous membrane obtained were tested for pepsin activity after the method of Mett. When the animal had completely recovered from the interference it was killed and similar pieces of mucous membrane from corresponding parts of the stomach were tested for their pepsin content.

In the fourth investigation the spleens were extirpated in a number of rats. After the animals had recovered from the operations a splenectomized rat and a control rat were killed, and the infusion of each stomach tested for its peptic power.

From these experiments Trampedach arrived at the conclusion that extirpation of the spleen has no diminishing influence on the digestive power of the stomach. He found no relation between the post-splenectomy lymphocytosis and the secretion of pepsin.

Rusca, in 1912, reported a case of splenomegalia malarica with torsion of the splenic pedicle and anemia. Splenectomy was performed; the anemia improved and ten days later gastric researches on the patient were made. By percussion and roentgenologically the stomach was found to be ptotic and the emptying time four hours. Ewald, Boas and Leube test-meals were used. An increase of free hydrochloric acid was found but not invariably, and a constant and marked diminution in the content of pepsin, more striking with the method of Gross than with that of Mett. After Leube's meal a diminution in the power of fragmentation and disintegration of meat fiber was quite in evidence microscopically. Gastric motor function was good.

Rusca produced cirrhosis of the spleen in a dog by injecting the pneumobacillus of Friedländer and found diminished peptic activity thereafter. He surmised that the sclerosis thus caused interfered with the gastrosplenic circulation described by Baccelli and so hindered the afflux of the hypothetical activating ferment to the stomach.

In two cases of leukemia and two of malaria Rusca determined the size of the spleen, the leukocyte count, the relative lymphocytosis, the gastric acidity, the gastric activity of digestion of meat fibers and the trypsin content of the feces, but he could reach no conclusions from his results as to the rôle of the spleen in digestion. One patient with leukemia showed a marked reduction of pepsin, whereas in the others the gastric digestion was normal. All, however, had hyperchlorhydria.

Rusca also studied in 1912 the gastric function in six dogs before and after splenectomy, using an Ewald test-meal of 50 gm. bread and 250 c.c. water, and extracting it with the stomach-tube three-quarters of an hour after ingestion. He found a slight diminution in pepsin after splenectomy and slight unimportant variations in the amount of total acids. He obtained evidence neither of digestion of starch nor of lipolytic activity. There was no free hydrochloric acid. The dogs had voracious appetites and gained weight. The diminution in peptic power he thought to be compensated for by the augmentation of appetite and the greater amount of aliment taken.

Rusca likewise observed that in a dog with a gastric fistula following splenectomy peptic activity decreased somewhat after meals of milk, meat and oil. In experiments on a bitch which had been splenectomized about three months previously he found a marked persisting voracity and could not corroborate Gross's findings that the pepsin power returned to normal after several months.

He considered the question of the influence of the spleen on digestion not yet settled. In just what manner the spleen acts he thought it not possible to say; probably it has a purely vascular influence, forming a sort of receptacle for the blood which accumulates there in its ample lacunæ coincidently with the congestion of all the abdominal organs during digestion. The spleen then contracts and sends the blood through the peculiar gastrosplenic system to the peptic cells, offering there in greater quantity the necessary pabulum for the elaboration of pepsin.

Soler and Madero made an experimental communication in 1912 with regard to this subject. They used dogs with Pawlow stomach pouches. At first they had great difficulty in keeping the dogs alive; the animals lost 40 per cent. of their initial weight and died within from one to one and one-half months. After diets of milk and of meat an immediate and marked drop was found in the peptic power of the gastric secretion following removal of the spleen, while coincident and parallel with this the erythrocyte count diminished. Pepsin was measured by Mett's tubes, amylolytic ferment (?) by titration with Fehling's solution (after clearing with lead subacetate the sugar solution acted on), lipase by allowing 2 c.c. of juice to stand ten hours at 38° C. with 1 c.c. of olive oil, dissolving this then with 50 c.c. of alcohol and titrating with sodium hydroxide the amount of fatty acids developed. They noted a diminution of lipase after splenectomy, and concluded that there is a like diminution of gastric amylase if such exists. More lipase was secreted after a meal of milk than after one of meat. By computing the peptic activity in digestive units (obtained by multiplying the amount of secretion by the quantity of pepsin) they found a greater drop in the amount of pepsin after splenectomy than when this was measured directly by the number of millimeters of Mett's tubes digested. With both milk and meat secretory meals the digestive curve before splenectomy rose to the highest points the first and second hour and dropped fairly acutely to end in seven hours. After splenectomy the fall in the digestive curve was more gradual and did not reach normal for from nine to twelve hours. This they considered was because the digestive units were fewer and thus the juice would have to act longer to accomplish a given amount of digestion. Soler and Madero concluded: "We think, therefore, in view of the proof as we have offered it, that the spleen is an organ which evidently assists physiologically in the elaboration of the gastric ferments."

In 1915 Soler and Madero published a paper reviewing their former work and discussing it and their methods in detail. Furthermore, they gave the results of a series of injections with splenic products, "hormonal," and decoctions and macerations of dog's spleen. Invariably they obtained an increase in peptic activity after such injections. Some of these experiments were performed on a dog splenectomized three years previously. This influence of splenic extract they determined was not due to the solution used for decocting and macerating spleens, for injected alone in greater amounts it had no effects. Next they studied the influence of the serum of the splenic vein as compared with that of the splenic artery and found it much superior in stimulating effect. They considered this distinctive action due to elements in the spleen, most probably to the leukocytes which exist in this organ in such enormous quantity. Later they used extracts of lymph glands, of the spleen, leukocytes and washed erythrocytes (which probably contained a large amount of leukocytic material) both of the dog and of the horse, with similar results. The mesenteric lymph glands alone gave negative findings in contrast to those mentioned, their excitosecretory function on the stomach being nil. They found after the injection of splenic products that the erythrocytes increased as much as the leukocytes.

In *resume*, Soler and Madero concluded that (1) splenectomy diminishes the digestive power of the stomach; (2) the injection of macerations and decoctions of the spleen whether obtained from the same or different species increases the digestive power of the stomach; (3) the splenectomized animals diminish in weight to reach a stationary level, but require double the amount of nutriment for sustenance; (4) the injection of splenic products provokes a frank augmentation of weight in the dogs splenectomized, but has little or no influence on those not splenectomized; and (5) the blood formula shows that in splenectomy the erythrocytes follow a curve parallel with that of the fermentative power, being inverse to that of the leukocytes, while following the injection of macerated material (splenic infusion) the augmentation of both occurs conjointly.

## EXPERIMENTAL METHODS.

In the present experimental study healthy female dogs weighing on the average about 10 kg. were used. Accessory stomachs or fundic sacs with blood and nerve supply intact and communicating with the outside were made according to a slightly modified Pawlow technic. Fifteen animals were prepared, on three of which only were complete data obtained before and after splenectomy. Most of the others succumbed to distemper, then epidemic in the laboratory, a few to the primary operation.

The dogs were placed in pillories and the juice collected by inserting into the pouches large fenestrated rubber tubes with wide funnel-shaped cuffs which were held snugly against the abdominal wall by an appropriate harness. The loss of juice in collection was negligible.

However, digestion of the skin about the openings of the miniature stomachs could not be prevented entirely although it was obviated as much as possible by the use of divers ointments, beds of sand or shavings, continuous drainage by leaving the tube in place at all times and so forth.

The animals were deprived of food on the evening previous to the experiment and of water one hour before the giving of the secretory meal, which consisted of raw meat cut into small cubes. The diet at other times was bread and milk. In some instances the amount of continuous gastric secretion was determined by collecting the juice for one hour previous to feeding. In all cases the dogs lost some weight after each operative procedure, but, on the whole, their state of nutrition remained good with the exception of those which developed distemper and of Dog. E.

The gastric juice was collected for six hours after feeding, the amount measured, the free and total acidity ascertained by titrating 1 c.c. of clear juice diluted with 25 c.c. of distilled water, with dimethylamidoazobenzol and phenolphthalein as indicators, and the pepsin activity determined by Mett's method. Fortieth normal sodium hydroxide was used for the titration, the acidity found being expressed in percentages of hydrochloric acid; and 1 c.c. of juice diluted with 5 c.c. of tenth normal hydrochloric acid placed with Mett's tubes (egg albumen coagulated just below boiling) at 39° C. for twenty-four hours for the digestive strength, the result being expressed directly in the number of millimeters of albumen digested (average of four readings). When a norm was established for the gastric secretion in each instance the spleen was removed under ether anesthesia preceded by an injection of one-fourth grain morphin and one one-hundred and fiftieth grain atropin. Determinations were again made on the gastric secretion as before, and at the conclusion of each experiment a necropsy was performed to rule out the presence of unremoved or accessory splenic tissue.

## EXPERIMENTAL DATA.

The protocols of experimental data are as follows:

PROTOCOL 1.—DOG D: NORMAL WITHOUT SPLENECTOMY. PAWLOW POUCH MADE APRIL 11, 1917. SECRETORY MEAL, 100 GM. MEAT.

| Date, 1917. | Amount of juice for six hours. c.c. | Free acid. | Combined acid. | Total acidity. | Pepsin (Mett's tubes), mm. |
|---|---|---|---|---|---|
| April 16 . . . . | 18.2 | 0.09 | 0.11 | 0.20 | 3.70 |
| 17 . . . . | 24.6 | 0.24 | 0.09 | 0.33 | 3.05 |
| 18 . . . . | 9.7 | 0.08 | 0.08 | 0.16 | 3.05 |
| 19 . . . . | 15.8 | 0.09 | 0.09 | 0.18 | 3.05 |
| 20 . . . . | 14.3 | 0.04 | 0.08 | 0.12 | 4.30 |
| Averages . . . | 16.5 | 0.11 | 0.09 | 0.20 | 3.43 |

Dog D remained in good condition until April 21 when symptoms of distemper appeared. The dog died from distemper April 28.

## PROTOCOL 2.—DOG F: NORMAL WITHOUT SPLENECTOMY. PAWLOW POUCH MADE APRIL 19, 1917. SECRETORY MEAL, 150 GM. MEAT.

| Date, 1917. | Amount of juice for six hours. c.c. | Free acid. | Combined acid. | Total acidity. | Pepsin (Mett's tubes), mm. |
|---|---|---|---|---|---|
| April 23 | 14.0 | 0.09 | 0.16 | 0.25 | 2.75 |
| 24 | 49.0 | 0.00 | 0.20 | 0.20 | 2.70 |
| 25 | 56.0 | 0.09 | 0.17 | 0.26 | 1.50 |
| 26 | 43.3 | 0.07 | 0.20 | 0.27 | 2.90 |
| 27 | 43.9 | 0.00 | 0.20 | 0.20 | 3.85 |
| 28 | 42.6 | 0.00 | 0.16 | 0.16 | 2.30 |
| 29 | 34.3 | 0.00 | 0.20 | 0.20 | 5.00 |
| 30 | 32.2 | 0.00 | 0.14 | 0.14 | 3.05 |
| May 14 | 19.6 | 0.00 | 0.07 | 0.07 | 2.00 |
| 16 | 28.0 | 0.00 | 0.18 | 0.18 | 4.60 |
| Average | 37.3 | 0.25 | 0.168 | 0.193 | 3.065 |

Dog F remained in good condition until May 1 when it developed a mild distemper and lost weight markedly; it recovered May 13, and two more determinations were made. A marked inanition developed, however, and because of this and the extreme variability of the normal determinations the experiment was abandoned.

## PROTOCOL 3.—DOG L: PAWLOW POUCH MADE JUNE 10 AND SPLENECTOMY PERFORMED AUGUST 1, 1917. SECRETORY MEAL, 150 GM. MEAT.

| Date, 1917. | Amount of juice for six hours. c.c. | Free acid. | Combined acid. | Total acidity. | Pepsin (Mett's tubes), mm. |
|---|---|---|---|---|---|
| | | BEFORE SPLENECTOMY. | | | |
| June 30 | 12.0 | 0.17 | 0.09 | 0.26 | 3.25 |
| July 2 | 14.0 | 0.17 | 0.10 | 0.27 | 4.00 |
| 3 | 21.0 | 0.16 | 0.10 | 0.26 | 3.875 |
| 4 | 17.0 | 0.18 | 0.09 | 0.27 | 3.25 |
| 7 | 14.0 | 0.16 | 0.10 | 0.26 | 3.5 |
| 8 | 16.0 | 0.21 | 0.07 | 0.28 | 3.375 |
| 10 | 14.6 | 0.12 | 0.10 | 0.22 | 3.68 |
| 11 | 10.0 | 0.05 | 0.14 | 0.19 | 3.375 |
| 12 | 27.0 | 0.19 | 0.15 | 0.34 | 1.50 |
| 24 | 24.0 | 0.21 | 0.11 | 0.32 | 2.625 |
| 26 | 30.0 | 0.15 | 0.26 | 0.41 | 2.625 |
| 28 | 39.0 | 0.18 | 0.07 | 0.25 | 1.80 |
| | | AFTER SPLENECTOMY. | | | |
| Aug. 4 | 26.7 | 0.32 | 0.07 | 0.39 | 2.20 |
| 5 | 12.0 | 0.20 | 0.07 | 0.27 | 3.50 |
| 6 | 12.0 | 0.23 | 0.09 | 0.32 | 3.50 |
| 7 | 18.0 | 0.16 | 0.10 | 0.26 | 3.80 |
| 8 | 40.0 | 0.21 | 0.11 | 0.32 | 3.70 |
| 9 | 15.0 | 0.08 | 0.16 | 0.24 | 3.25 |
| 10 | 20.0 | 0.36 | 0.10 | 0.46 | 3.00 |
| 11 | 18.4 | 0.15 | 0.08 | 0.23 | 3.85 |
| 12 | 16.0 | 0.10 | 0.07 | 0.17 | 2.68 |
| | | AVERAGE BEFORE SPLENECTOMY. | | | |
| | 19.9 | 0.16 | 0.12 | 0.28 | 3.05 |
| | | AVERAGE AFTER SPLENECTOMY. | | | |
| | 14.9 | 0.20 | 0.095 | 0.295 | 3.25 |

Dog L remained in good condition throughout the experiment and at its conclusion was killed by etherization. No accessory splenic tissue was found at necropsy.

### PROTOCOL 4.—DOG M: PAWLOW POUCH MADE JUNE 17. SPLENECTOMY PERFORMED JULY 31, 1917. SECRETORY MEAL, 150 GM. MEAT.

| Date, 1917. | Amount of juice for six hours. c.c. | Free acid. | Combined acid. | Total acidity. | Pepsin (Mett's tubes), mm. |
|---|---|---|---|---|---|
| Before Splenectomy. | | | | | |
| July 4 | 15.0 | 0.34 | 0.09 | 0.43 | 4.0 |
| 6 | 18.0 | 0.29 | 0.10 | 0.39 | 4.1 |
| 7 | 19.0 | 0.15 | 0.16 | 0.31 | 4.5 |
| 8 | 20.0 | 0.21 | 0.13 | 0.34 | 2.6 |
| 9 | 19.7 | 0.14 | 0.17 | 0.31 | 2.04 |
| 10 | 24.0 | 0.17 | 0.21 | 0.38 | 3.16 |
| 11 | 34.0 | 0.35 | 0.10 | 0.45 | 3.75 |
| 12 | 25.0 | 0.10 | 0.13 | 0.33 | 3.00 |
| 24 | 15.0 | 0.15 | 0.29 | 0.44 | 3.50 |
| 26 | 18.0 | 0.13 | 0.26 | 0.39 | 3.00 |
| 28 | 30.4 | 0.23 | 0.16 | 0.39 | 3.85 |
| 29 | 20.0 | 0.36 | 0.11 | 0.47 | 2.875 |
| 30 | 25.0 | 0.27 | 0.11 | 0.38 | 2.69 |
| After Splenectomy. | | | | | |
| Aug. 4 | 14.4 | 0.16 | 0.15 | 0.31 | 2.40 |
| 5 | 13.0 | 0.20 | 0.15 | 0.35 | 3.50 |
| 6 | 16.0 | 0.21 | 0.11 | 0.32 | 3.60 |
| 7 | 23.0 | 0.25 | 0.16 | 0.41 | 3.60 |
| 8 | 19.0 | 0.23 | 0.15 | 0.38 | 3.44 |
| 9 | 30.0 | 0.29 | 0.12 | 0.41 | 3.50 |
| 10 | 17.0 | 0.15 | 0.22 | 0.37 | 4.00 |
| 11 | 19.2 | 0.13 | 0.11 | 0.24 | 2.90 |
| 12 | 17.0 | 0.14 | 0.15 | 0.29 | 3.30 |
| Average before Splenectomy. | | | | | |
| | 21.8 | 0.22 | 0.16 | 0.38 | 3.31 |
| Average after Splenectomy. | | | | | |
| | 18.7 | 0.20 | 0.15 | 0.35 | 3.31 |

Dog M remained in good condition throughout the experiment and at its conclusion was killed by etherization. No accessory splenic tissue was found at necropsy.

### TABLE 1.—DOG L: HOURLY DETERMINATIONS BEFORE AND AFTER SPLENECTOMY.

| Date, July 9, 1917. | Pepsin (Mett's tubes), mm. | Amount of juice, c.c. | Free acid. | Combined acid. | Total acidity. |
|---|---|---|---|---|---|
| Before Splenectomy. | | | | | |
| First hour | 5.00 | 4.20 | 0.11 | 0.09 | 0.20 |
| Second hour | 4.75 | 3.80 | 0.20 | 0.06 | 0.26 |
| Third hour | 3.75 | 3.20 | 0.18 | 0.07 | 0.25 |
| Fourth hour | 3.00 | 3.00 | 0.18 | 0.05 | 0.23 |
| Fifth hour | 2.90 | 2.00 | 0.12 | 0.04 | 0.16 |
| Sixth hour | 2.50 | 2.20 | 0.07 | 0.21 | 0.26 |
| After Splenectomy. | | | | | |
| August 2, 1917. | | | | | |
| First hour | 3.25 | 3.20 | 0.14 | 0.06 | 0.20 |
| Second hour | 2.50 | 3.60 | 0.13 | 0.07 | 0.20 |
| Third hour | 2.25 | 2.00 | 0.10 | 0.07 | 0.17 |
| Fourth hour | 2.25 | 2.60 | 0.06 | 0.08 | 0.14 |
| Fifth hour | 2.31 | 2.40 | 0.09 | 0.06 | 0.15 |
| Sixth hour | 3.44 | 2.20 | 0.06 | 0.07 | 0.13 |

PROTOCOL 5.—DOG E: HEIDENHAIN POUCH MADE APRIL 13. SPLENECTOMY PERFORMED APRIL 26, 1917, AT 9 P.M. SECRETORY MEAL, 100 GM. MEAT.

| Date. | Hour preceding feeding. | Amount collected each hour. | | | | | | Amount of mucus. | Pure juice. | Total amount collected | Free acid. | Combined acid. | Total acidity. | Pepsin (Mett's tubes). |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | First. | Second. | Third. | Fourth. | Fifth. | Sixth. | | | | | | | |
| 1917. | | | | | | | | | | | | | | |
| Before Splenectomy. | | | | | | | | | | | | | | |
| | | C.c. | C.c. | C.c. | C.c. | C.c. | C.c. | C.c. | C.c. | C.c. | | | | |
| April 18 | 2.8 | 11.4 | 11.0 | 12.0 | 14.8 | 9.4 | 7.2 | 3.8 | 62.0 | 65.8 | 0.32 | 0.10 | 0.42 | 2.00 |
| 19 | ... | 6.2 | 5.0 | 7.6 | 8.4 | 11.0 | 9.2 | 1.8 | 45.6 | 47.4 | 0.36 | 0.07 | 0.43 | 2.10 |
| 20 | 2.6 | 6.8 | 7.2 | 10.0 | 9.2 | 6.5 | 3.7 | ... | ... | 45.4 | 0.34 | 0.09 | 0.43 | 1.88 |
| 21 | 3.5 | 9.8 | 5.2 | 10.6 | 12.7 | 9.6 | 5.1 | 2.4 | 50.6 | 53.0 | 0.32 | 0.10 | 0.42 | 2.10 |
| 22 | 1.8 | 11.2 | 15.2 | 13.0 | 7.0 | 4.4 | 3.2 | 0.8 | 52.3 | 54.0 | 0.41 | 0.06 | 0.47 | 1.92 |
| 23 | 1.2 | 9.0 | 17.8 | 20.8 | 11.3 | 13.7 | 12.0 | 1.6 | 83.1 | 84.7 | 0.41 | 0.06 | 0.47 | 1.95 |
| 24 | 2.4 | 11.2 | 7.0 | 5.4 | 8.0 | 7.6 | 7.0 | 0.8 | 45.4 | 46.2 | 0.40 | 0.05 | 0.45 | 2.14 |
| 25 | 1.0 | 5.9 | 5.6 | 5.4 | 7.4 | 6.8 | 6.5 | 0.8 | 36.2 | 37.0 | 0.37 | 0.08 | 0.45 | 1.83 |
| 26 | 1.2 | 10.2 | 13.6 | 17.6 | 13.6 | 12.8 | 9.4 | 0.6 | 76.6 | 77.2 | 0.46 | 0.04 | 0.50 | 1.81 |
| After Splenectomy. | | | | | | | | | | | | | | |
| April 27 | ... | 7.0 | 4.0 | 7.0 | 3.8 | 2.8 | 2.5 | 1.4 | 25.7 | 27.1 | 0.36 | 0.09 | 0.45 | 1.56 |
| 28 | 0.7 | 8.0 | 9.4 | 8.7 | 5.2 | 5.0 | 5.4 | 3.0 | 38.7 | 41.7 | 0.40 | 0.05 | 0.45 | 1.50 |
| 29 | 0.8 | 10.2 | 6.8 | 6.4 | 7.8 | 5.6 | 6.6 | 0.6 | 42.8 | 43.4 | 0.43 | 0.04 | 0.47 | 1.74 |
| 30 | 3.4 | 15.2 | 22.0 | 21.6 | 14.2 | 11.2 | 12.0 | 0.8 | 95.4 | 96.2 | 0.46 | 0.04 | 0.50 | 1.87 |
| May 1 | 2.8 | 6.2 | 11.6 | 12.8 | 6.2 | 3.8 | 2.6 | 2.2 | 41.6 | 43.8 | 0.34 | 0.08 | 0.42 | 2.10 |
| 2 | 1.6 | 10.0 | 10.2 | 8.0 | 9.2 | 6.8 | 4.0 | 2.4 | 45.8 | 48.0 | 0.33 | 0.09 | 0.42 | 2.00 |
| 3 | 2.4 | 11.8 | 9.4 | 12.8 | 12.6 | 6.6 | 5.6 | 2.2 | 56.6 | 58.8 | 0.39 | 0.07 | 0.46 | 2.00 |
| 4 | ... | 5.6 | 7.2 | 7.3 | 7.6 | 7.2 | 6.2 | 2.4 | 38.7 | 41.1 | 0.33 | 0.05 | 0.38 | 2.00 |
| 5 | ... | 5.2 | 5.2 | 6.8 | 6.2 | 6.0 | 4.8 | 1.4 | 32.8 | 34.2 | 0.30 | 0.60 | 0.36 | 1.85 |
| Average before Splenectomy. | | | | | | | | | | | | | | |
| | 2.08 | 9.1 | 9.7 | 11.6 | 10.3 | 9.1 | 7.0 | 1.6 | 56.6 | 57.0 | 0.38 | 0.07 | 0.45 | 1.97 |
| Average after Splenectomy; First Two Days Omitted. | | | | | | | | | | | | | | |
| | 2.5 | 9.2 | 10.3 | 10.8 | 9.2 | 7.0 | 6.0 | 1.5 | 50.5 | 52.2 | 0.37 | 0.06 | 0.43 | 1.94 |

Dog E began losing weight immediately after the operation and lost steadily and progressively until its death, May 9. No other abnormal findings, save the development of bloody stools the last forty-eight hours of life, were noted. At necropsy the isthmus connecting the pouch to the main stomach was very small, making it probable that the vagus fibers to the pouch were partially, if not totally, severed at the time of the first operation. There was no accessory splenic tissue. No cause for death could be found.

TABLE 2.—DOG M: HOURLY DETERMINATIONS BEFORE AND AFTER SPLENECTOMY.

BEFORE SPLENECTOMY.

| | Pepsin (Mett's tubes). | | | Amount of juice. | | | Free acid. | | | Combined acid. | | | Total acidity. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | July 9, 1917. | July 28, 1917. | Average. | July 9, 1917. | July 28, 1917. | Average. | July 9, 1917. | July 28, 1917. | Average. | July 9, 1917. | July 28, 1917. | Average. | July 9, 1917. | July 28, 1917. | Average. |
| | Mm. | Mm. | Mm. | C.c. | C.c. | C.c. | | | | | | | | | |
| First hour . . . | 2.80 | 4.30 | 3.55 | 3.0 | 9.0 | 6.1 | 0.17 | 0.22 | 0.195 | 0.17 | 0.14 | 0.155 | 0.34 | 0.36 | 0.35 |
| Second hour . . | 1.50 | 3.60 | 2.55 | 3.3 | 6.8 | 5.05 | 0.17 | 0.30 | 0.235 | 0.21 | 0.16 | 0.185 | 0.38 | 0.46 | 0.42 |
| Third hour . . . | 1.87 | 3.50 | 2.685 | 2.6 | 4.0 | 3.3 | 0.14 | 0.26 | 0.20 | 0.17 | 0.15 | 0.16 | 0.31 | 0.41 | 0.36 |
| Fourth hour . . | 1.70 | 3.50 | 2.60 | 3.6 | 4.0 | 3.8 | 0.16 | 0.25 | 0.205 | 0.20 | 0.16 | 0.18 | 0.36 | 0.41 | 0.385 |
| Fifth hour . . . | 2.56 | 4.00 | 3.28 | 3.2 | 3.4 | 3.3 | 0.15 | 0.19 | 0.17 | 0.18 | 0.17 | 0.175 | 0.33 | 0.36 | 0.345 |
| Sixth hour . . . | 2.61 | 3.80 | 3.205 | 2.4 | 3.0 | 2.7 | 0.16 | 0.09 | 0.125 | 0.18 | 0.19 | 0.185 | 0.34 | 0.28 | 0.31 |

AFTER SPLENECTOMY.

| | Aug. 11, 1917. | Aug. 12, 1917. | Average. | Aug. 11, 1917. | Aug. 12, 1917. | Average. | Aug. 11, 1917. | Aug. 12, 1917. | Average. | Aug. 11, 1917. | Aug. 12, 1917. | Average. | Aug. 11, 1917. | Aug. 12, 1917. | Average. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First hour . . . | 4.60 | 4.75 | 4.375 | 2.2 | 3.6 | 2.9 | 0.00 | 0.08 | 0.04 | 0.12 | 0.17 | 0.145 | 0.12 | 0.25 | 0.185 |
| Second hour . . | 4.35 | 3.19 | 3.77 | 3.0 | 3.6 | 3.3 | 0.04 | 0.20 | 0.12 | 0.21 | 0.15 | 0.18 | 0.25 | 0.35 | 0.30 |
| Third hour . . . | 3.55 | 2.75 | 3.15 | 4.2 | 2.2 | 3.2 | 0.11 | 0.16 | 0.135 | 0.16 | 0.16 | 0.16 | 0.27 | 0.32 | 0.295 |
| Fourth hour . . . | 2.34 | 2.60 | 2.47 | 3.0 | 2.8 | 2.9 | 0.12 | 0.14 | 0.13 | 0.17 | 0.12 | 0.145 | 0.29 | 0.26 | 0.275 |
| Fifth hour . . . | 2.65 | 2.44 | 2.545 | 3.8 | 2.6 | 3.2 | 0.09 | 0.15 | 0.12 | 0.20 | 0.11 | 0.155 | 0.29 | 0.26 | 0.275 |
| Sixth hour . . . | 3.27 | 3.60 | 3.435 | 3.0 | 2.2 | 2.6 | 0.07 | 0.11 | 0.09 | 0.21 | 0.16 | 0.185 | 0.28 | 0.27 | 0.275 |

## TABLE 3.—DOG E: HOURLY DETERMINATIONS BEFORE AND AFTER SPLENECTOMY.

### BEFORE SPLENECTOMY.

| | Pepsin (Mett's tubes). | | | Free acid. | | | Combined acid. | | | Total acidity. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mar. 24, 1917. | Mar. 25, 1917. | Average. | Mar. 24, 1917. | Mar. 25, 1917. | Average. | Mar. 24, 1917. | Mar. 25, 1917. | Average. | Mar. 24, 1917. | Mar. 25, 1917. | Average. |
| | Mm. | Mm. | Mm. | | | | | | | | | |
| First hour | 1.80 | 2.70 | 2.25 | 0.40 | 0.32 | 0.36 | 0.06 | 0.04 | 0.05 | 0.46 | 0.36 | 0.41 |
| Second hour | 1.35 | 2.05 | 1.70 | 0.44 | 0.36 | 0.40 | 0.04 | 0.04 | 0.04 | 0.48 | 0.40 | 0.44 |
| Third hour | 1.65 | 1.70 | 1.695 | 0.39 | 0.36 | 0.375 | 0.05 | 0.04 | 0.044 | 0.44 | 0.40 | 0.42 |
| Fourth hour | 2.00 | 1.70 | 1.85 | 0.39 | 0.39 | 0.39 | 0.05 | 0.05 | 0.05 | 0.44 | 0.44 | 0.44 |
| Fifth hour | 1.75 | 1.40 | 1.575 | 0.41 | 0.38 | 0.405 | 0.05 | 0.06 | 0.055 | 0.46 | 0.44 | 0.45 |
| Sixth hour | 1.65 | 1.40 | 1.525 | 0.39 | 0.38 | 0.385 | 0.06 | 0.07 | 0.65 | 0.45 | 0.45 | 0.45 |

### AFTER SPLENECTOMY.

| | Mar. 28, 1917. | Mar. 30, 1917. | Average. | Mar. 28, 1917. | Mar. 30, 1917. | Average. | Mar. 28, 1917. | Mar. 30, 1917. | Average. | Mar. 28, 1917. | Mar. 30, 1917. | Average. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First hour | 2.80 | 2.00 | 2.40 | 0.43 | 0.39 | 0.41 | 0.04 | 0.08 | 0.06 | 0.47 | 0.47 | 0.47 |
| Second hour | 1.90 | 1.30 | 1.60 | 0.48 | 0.41 | 0.445 | 0.04 | 0.07 | 0.055 | 0.52 | 0.48 | 0.50 |
| Third hour | 1.45 | 1.50 | 1.475 | 0.48 | 0.40 | 0.44 | 0.04 | 0.07 | 0.055 | 0.52 | 0.47 | 0.495 |
| Fourth hour | 1.95 | 1.45 | 1.70 | 0.46 | 0.38 | 0.42 | 0.05 | 0.07 | 0.06 | 0.51 | 0.45 | 0.48 |
| Fifth hour | 1.75 | 1.15 | 1.45 | 0.46 | 0.34 | 0.40 | 0.04 | 0.09 | 0.065 | 0.50 | 0.43 | 0.465 |
| Sixth hour | 1.40 | 1.60 | 1.50 | 0.44 | 0.34 | 0.39 | 0.05 | 0.06 | 0.055 | 0.49 | 0.40 | 0.0445 |

The peptic strengths and acidities in Protocol 5 corresponding to those of the four days in Table 3 were obtained by multiplying; for example, each hourly strength of pepsin by the amount of juice collected the corresponding hour, these added, and the total divided by the total amount of juice collected that day.

## Review of Experimental Data.

Our experimental data show that splenectomy had apparently little influence on gastric secretion.

Protocols 1 and 2 illustrate the normal findings of gastric secretion under the conditions of this study and serve as controls for the splenectomized animals of Protocols 3 and 4. From the first four protocols it is seen that normally an amount of pepsin is secreted sufficient to digest approximately 3 mm. of egg albumen (Mett's tubes) in twenty-four hours. Ordinarily the peptic activity as illustrated in Protocols 2, 3 and 4 is quite constant and fluctuates little from day to day; the inconstancy shown in Protocol 2 is exceptional and the most marked that we have observed. The daily variation, however, in the proteolytic power of the juice in the cases of Dog L and Dog M was less marked after splenectomy. It is doubtful whether any significance can be attached to this.

In Protocol 4 the total acidity is about that generally cited as normal, whereas Protocols 1, 2 and 3 show a subnormal acidity, approximately 0.2 per cent. The total acidity in each instance is likewise fairly consistent in amount, but not so consistent as the pepsin. On the other hand the amounts of free and combined acid fluctuate widely, in such manner, however, as to be mutually complementary. Hence changes in the relative proportions of these acidities after extirpation of the spleen mean little. It is interesting to note that Dog F showed the presence of free acid on a few occasions only.

In the quantity of secretion obtained in six hours the important determining factors are the size of the Pawlow pouch and the amount of the secretory meal. In the experiments under discussion about 25 c.c. for each 150 gm. of meat given were secreted by the miniature stomach. This is rather a low rate, but the pouch in each instance was small. The daily variation in the quantity of juice was quite marked, depending probably to a large extent on psychic and other extrinsic factors influencing the stomach through its secretory and motor nerves. Because of this variability slight changes following any experimental procedure cannot be given the weight otherwise to be accredited them.

In Protocols 3 and 4 the only noteworthy result following splenectomy was a diminution in the quantity of secretion, 25 per cent. decrease in Dog. L and 14 per cent. in Dog M (Fig. 1). This might possibly have been due to the interference with, and resulting decrease of, the gastric blood supply consequent on the operation, especially the injury to the gastrosplenic circulation through the vasa brevia. The determinations in each case were made too soon after the removal of the spleen for the post-splenectomy anemia to play a causative role.

The data given in Protocol 5 are considered separately, for, as was found at necropsy, we were dealing with an accessory stomach of the Heidenhain type rather than of that of Pawlow as we thought. This lack of nervous control over the pouch gave noteworthy differences from the normal secretory findings: (1) With a secretory meal of only 100 gm. of meat, the amount of juice obtained in six hours, 50 c.c., was twice that of the other dogs with a meal of 150 gm.; (2) the daily fluctuation in amount of juice was less; (3) the free acidity was persistently and consistently high, approximately 0.4 per cent.; and (4) the strength of pepsin was low (2 mm.) but quite constant. This daily non-variability of the quantity of juice secreted, of the acidities, and of the proteolytic power would be expected from severance of the pouch from extrinsic influences through the nervous system. Since no cause for death could be found in this dog the idea suggests itself that possibly the loss of large quantities of juice from daily secretory meals, especially the loss of such great quantities of acid as occurred in this case, may have set up metabolic and acid-base-equilibrium disturbances sufficient to cause death.

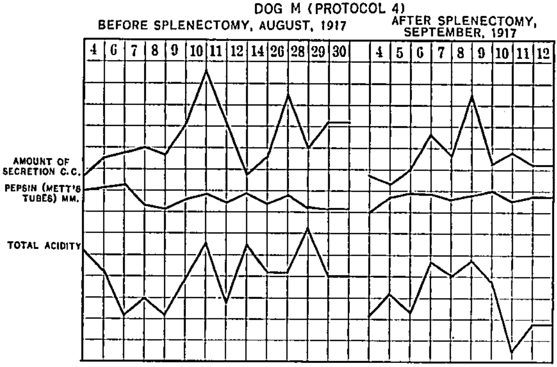

Fig. 1

Dog E of this experiment was splenectomized at 9 in the evening after it had had a secretory meal the same day, and was given a similar feeding the next morning, with the express purpose of seeing the immediate effect of splenectomy. After operation the pepsin strength was reduced, gradually rising to regain its normal about the third or fourth day. However, it seems logical to attribute this fall in proteolytic activity to the effect of the operation—anesthetic with following nausea and decrease in appetite, shock resulting from the operative trauma with the reaction on all the body processes, and the effect of the atropin, given just before the operation, in checking gastric secretion. Hence it seems justifiable to omit from the general averages in this protocol the first two days after splenectomy, allowing this amount of time for recovery from the operation.

This experiment likewise shows no marked change in gastric secretion following splenectomy, though it is again noted that there is a decrease (8.5 per cent.) in the amount of juice obtained.

Tables 1, 2 and 3, and a portion of Protocol 5, give hourly determinations of gastric juice before and after splenectomy (Fig. 2). The average continuous secretion of juice from the pouch with the animal fasting was about 2 c.c. each hour in Dog E and much less than this in the other animals (figures not given). The amount of juice secreted each hour varied through wide limits. With the Heidenhain pouch it rose gradually to reach a maximum the third hour and then diminished; with the Pawlow pouch the maximum occurred at any of the first three hours, most frequently at the first.

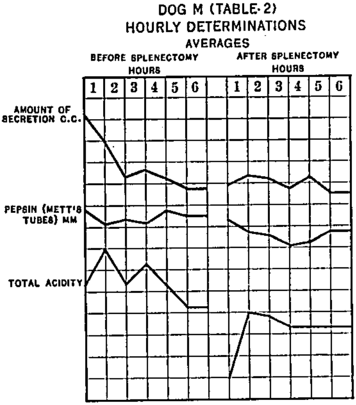

FIG. 2

The pepsin content in nearly all instances was greatest the first hour, then dropped to show frequently a later secondary slight rise. The free acid and total acidity, it will be noted, reached a maximum from the second to the third hour only to fall again, whereas the combined acid remained about constant. These results (save the amount of juice secreted each hour in Dog E, which corresponds more to the normal of an intact pouch on a milk diet) coincide with those given by Pawlow as the normal hourly variation in gastric secretion in dogs on a meat diet.

Our protocols show that after splenectomy there is no noteworthy change in the hourly variations of gastric secretion after a secretory meal.

## DISCUSSION.

As is true of almost every field of research on the spleen it is apparent that the experimental results of different investigators with regard to the relation of this gland to gastric secretion are widely different. Just where the reasons lie for this it is difficult to determine.

The methods used in the investigations of some of the workers are possibly open to criticism. It is well recognized that collection of gastric juice for analysis from a gastric fistula is not so satisfactory as from the Pawlow stomach, since the former admits of contamination with saliva and duodenal contents, and the secretory meal is not separated from the juice tested; in fact, almost any results can be obtained with a gastric fistula. Cubes of coagulated albumin for pepsin determination offer less accuracy than the Mett method, though the latter is not ideal; the surface of albumin exposed to the action of the pepsin is more variable and less easily controlled and the handling and weighing of the cubes fraught with possibilities of error. The data obtained clinically on splenectomized persons are of inconclusive value irrespective of results, since there is always present some disease process rendering splenectomy advisable which may enter into consideration, and, further, the unreliability of determinations of gastric secretions obtained through stomach tubes is notorious. Likewise in animals analyses of stomach contents obtained after a test-meal by means of the tube or by vomiting induced by apomorphin are to be questioned. Furthermore, some of the experiments were made without comparative control determinations before splenectomy, for example those of Gallenga and Gross, and the clinical researches of Silvestri and Rusca. In other instances insufficient experimental data were offered on which to base conclusions, for example Betti, who gave a few results obtained from only one dog.

The most recent researches, those of Soler and Madero, were carried on practically under the same experimental conditions as the present study, yet with greatly different results. In their papers they make no reference to preceding work and are alone in their maintenance of the theory that the spleen assists in the physiologic elaboration of several gastric ferments, pepsin, gastric lipase and gastric amylase (?) Their results with injections of splenic products, leukocytes, lymph glands and so forth are interesting and find support, so far as splenic extracts are concerned, in the observations of Tarulli and Pascucci.

The work of Trampedach is the most thorough, painstaking and exhaustive that has been done. His investigation like the present study, does not demonstrate any change in gastric secretion following splenectomy.

These findings are further corroborated by the general experience of clinicians that splenectomy in man has no obvious effect on gastric digestion. However, since pepsin normally is furnished in excess of the amount absolutely needed a slight diminution following removal of the spleen need not necessarily cause gastric symptoms (for example the absence of complaint in many cases of achylia), and hence clinical observations in themselves mean but little.

It does not follow that although the spleen has no pepsinogenic function it may not have some other relation to the stomach. Only further researches can elucidate this point. It seems likely, however, that at least the gastrosplenic circulation through the vasa brevia is of some significance, whether merely mechanically cannot be said. The hematemeses of the splenomegalies, especially those of splenic anemia, have been explained on the basis of gastric varices and obstruction to the gastrosplenic circulation, and from a clinical standpoint suggest at least a pathologic splenic-gastric interrelationship.

From a critical review of the literature and my experiments I am led to believe that the spleen does not exert any influence on gastric secretion except possibly in a circulatory manner suggested by finding a slight diminution in the amount of secretion following splenectomy.

## SUMMARY.

The spleen and the stomach from the earliest times have been supposed to possess some close interrelationship. Baccelli, in 1868, demonstrated a gastrosplenic circulation through the vasa brevia, and first put forward the theory that the spleen plays a role in the elaboration of pepsin. Subsequent studies of this question have been made on dogs by testing gastric secretion before and after splenectomy. This has been done by the use of gastric fistulas and Pawlow pouches and by the removal of secretory meals through the stomach-tube. Similar studies on humans have been made by gastric analyses after splenectomy for various reasons. The results of these experiments have been contradictory. They may be summarized as follows:

1. Removal of the spleen causes a diminution of the proteolytic power of the gastric juice (Tarulli and Pascucci, Gallenga, Betti, Gross, Rusca, Soler and Madero).
2. Injection of splenic extracts (Tarulli and Pascucci, Soler and Madero) and of leukocytes and of extracts of lymph glands (Soler and Madero) increase the proteolytic power of the gastric juice of splenectomized animals.
3. Removal of the spleen causes an augmentation of the proteolytic power of the gastric juice (Silvestri, Tini).

4. Removal of the spleen has no effect whatsoever on gastric secretion (Trampedach).

The chief theory put forward by the first group of investigators has been that the spleen gives to the blood stream during digestion a substance which activates or leads to the further elaboration of the gastric enzymes, especially pepsin.

In this experimental study I have reported data concerning the gastric secretion findings before and after splenectomy on three dogs with accessory stomach pouches (secretory meal of meat) and on two similar dogs serving as controls. Removal of the spleen in these experiments caused no noteworthy changes in gastric secretion except a slight diminution in the quantity of gastric juice obtained.

I am led to conclude from my experimental inquiries and a critical review of the literature that a definite pepsinogenic function of the spleen has not been demonstrated and that the relation of the spleen to gastric secretion is probably merely vascular, the diminution in the amount of juice secreted after splenectomy being attributable to decreased gastric blood supply from injury to the gastrosplenic circulation.

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# EVENTRATION OF THE DIAPHRAGM, WITH REPORT OF A CASE.[1]

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Among the rare lesions of the diaphragm is the condition originally described by Petit in 1790 and termed by him eventration. This term, though generally used, is a misnomer because no abnormal opening of the diaphragm exists. Such an opening constitutes a hernia diaphragmatica vera when the projecting abdominal viscera are covered with peritoneum or a hernia diaphragmatica spuria when no peritoneal covering exists. In eventration there is simply a thinning or relaxation of the diaphragm, the layers remaining intact and the structure assuming an elevated or higher position than normal. Isolated writers have preferred such terms as these: "high position," "elevation," "dilatation," "relaxation" and "congenital insufficiency." Bayne-Jones, in 1916, collected the reported cases to that time and reported one of his own, making 45 in all. Since that time we have been able to find reports of 2 more. These cases with the one we report make a total of 48 cases on record at the present writing.

With regard to the etiology the weight of evidence would seem to favor a congenital origin. Some of the arguments advanced are (1) its occurrence in the fetus and the newborn, (2) its association with other congenital anomalies, (3) the involvement of the left side in almost all cases, which coincides with the complexity of the development of the left diaphragm, and (4) the absence of compression of the lung and contiguous structures.

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